Bringing Energy Efficiency for Hospital Building through the Conservative and Preventive Measures

Sathwik Reddy, Sayali Sandbhor, Vaishnavi Dabir

Abstract: The energy consumption of hospital buildings, have increased due to embedment of sophisticated equipment pertaining to advent of technology. Factors affecting energy consumptions are air quality monitoring, high maintenance of sophisticated machineries, accurate sanitization of premises, high load of patients to doctor ratio in India which is 1596:1 as compared to regulation of 1000:1 prescribed by World Health Organization (WHO). Confederation of Indian Industry (CII) reported that nearly 60% of health care services and hospitals do not meet the minimum of Energy Performance Index (EPI) criteria. Energy Conservation Building Code (ECBC) of India shows that hospitals in India have a potential to achieve 42% energy saving by implementing energy efficient measures. Hence, there is a dire need to assess the parameters contributing to heavy energy consumption and the conservative and preventive measures need to be addressed. Literature indicates incorporation of efficient domestic water heating techniques, boilers, usage of renewable energies, thermal insulation improvement, optimal building design, improvement of air conditioning and heating systems, optimizing electric energy installations etc as possible techniques for achieving energy efficiency. A compile of best practices proposed from literature as compared to the regulations made by ECBC, CII, MEDA, and GBC (Green building council) is made in this paper. HVAC being the highest contributing system for energy consumption, IoT based working models are prepared and proposed for application; suitability of adoption of the system is discussed.

Index Terms: Green building, energy, consumption, energy saving, hospital building, preventive measures

I.INTRODUCTION

Hospital buildings require continuous functioning without interruption, which leads to ranking them to be second most to use a large amount of energy in the building sector. The energy consumption in the new hospital buildings is increased compared to older building due to usage of sophisticated equipment [1].

In Indian health care sector, the World Health Organization (WHO) prescribed doctor to patient ratio is 1:1000, whereas the current ratio is 1: 1596 as per an article in Indian newspaper 'Times of India' April 3,2018, the doctor-patient ratio in India is healthy[2]. This has charged the engine for overall development of healthcare sector, leading to increase in provision of infrastructural facilities. Increased rate of growth of the sector has led to India's third rank among the health markets across the globe in incremental increase. Cost effective treatment in the country is also attracting a good number of patients from across the world.

II.LITERATURE REVIEW

A study on emission of CO_2 from different types of buildings in England was recently conducted. The study has shown that 8 buildings out of the top 10 most polluting buildings are hospitals [3]. The number of hospitals and sophisticated equipment usage has been increasing continuously, offering greater scope for energy saving. Energy saving would further help in lowering energy costs and lowering the emission of CO_2, resulting in enhancing air quality. A study undertaken by Energy Conservation Building Code (ECBC) [4], India demonstrates that Indian hospitals have a potential to conserve 42% of the energy consumption by implementation of energy efficient measures [5]. A recent report by Confederation of Indian Industry (CII) states that almost 60% of the health care services and hospitals under study did not meet the minimum criteria of Energy Performance Index (EPI), which is 200 kwh/sq.m/year [6].

With increasing in population the hospitals are also increasing to meet demand. The energy demand of hospitals needs to be given due attention as large amount energy is required for average Energy Use Intensity (EUI). Indian hospitals expend a 380 kwh/ sq.mt/ year against the benchmark of is 200 kwh/ sq.mt/ year [7].

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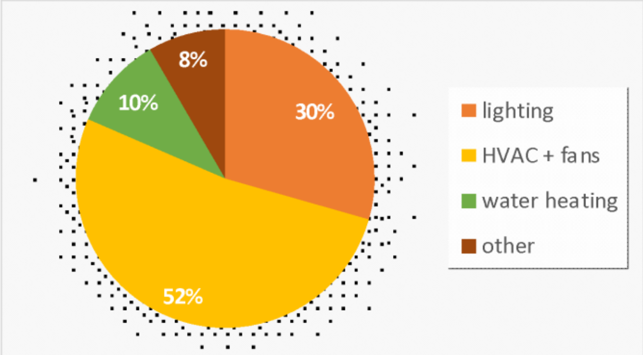

Figure 1: Energy breakdown in Indian hospitals

Healthcare buildings are important part of the economy in developed countries, considering the large amounts of energy consumed by them [8]. The Air conditioning and heating systems (HVAC) consumes large energy (over 50%) [9]. Vanhoudt et.al. [10], demonstrated in a hospital in Belgium that instead of using conventional gas-based boilers and water chillers, the stored thermal energy can be used in combination with a heat pump resulting into saving 71% of the primary energy. During the service life of a hospital building, a change in occupancy pattern is possible, resulting into higher rates of energy consumption [11]. Kolokotsa et.al. [12] reported that, by implementing simple energy saving techniques, it's possible to save around 10% of primary energy consumption.

Standards for energy efficient hospital building

In India, Energy conservation building code (ECBC) was established in 2007 for promoting energy efficiency in the building sector. It provides design norms for Building, lighting, HVAC, water heating and electrical system. It defines Hospitals and sanatoria (healthcare) as "any building or a group of buildings under single management, which is used for housing persons suffering from physical limitations because of health or age and those incapable of self-preservation, for example, any hospitals, infirmaries, sanatoria and nursing homes." For energy recovery of all hospitality and healthcare, having systems of capacity higher than 2,100 liters/second, and ones in which minimum outdoor air supply is of 70%, it is recommended by the ECBC to use technology for air-to-air heat recovery with minimum 50% effectiveness in recovery. For generator sets operating on diesel and gas fire, when installed in hospital and healthcare facilities with built up area greater than 20,000 $m^{2.}$, technology should be incorporated to recover at least 50% of the heat consumed. The standard recommendation is as shown in Table 1.

CII (Confederation of Indian Industry) is an Indian business association working towards creation of a conducive environment to the growth of industry in the country. It plays a major role in India's development process. GBC green building council is a Non-profit-organization globally recognized to promote the transformation of built environment towards the goal of sustainability. MEDA is Maharashtra energy development agency, it functions with an objective to develop and promote use of renewable energy and boosting energy conservation in state of Maharashtra, India. All the government and non-government agencies work together towards a sustainable energy usage. The focus is on energy conservation and reduction in pollution.

Table 1: ECBC standards for energy efficiency

Standards	ECBC
Day light requirement	≥30% of total floor area. Analysis period fixed for 8 hours per day, anytime between 8:00 AM IST to 5:00 PM IST, resulting in 2,920 hours in total
EPI ratio(Energy performance Index)	≤ 1
Service water heating by solar	≥40%
Boiler efficiency (fuel utilization efficiency)	≥80%
Pump efficiency	≥70%
Surface reflectance	Wall 50% Floor 20% Ceiling 70%
Exit signs	≤ 5 watts (Internally-illuminated exit signs shall not exceed 5 Watts per face.)
LPD(light power density)	≥9.7(w/m^2)

Measures to improve energy consumption savings

In 2011, Taichung Tzu Chi, a Hospital from Taiwan expanded its beds from 381 to 1081 [13]. The subsequence was higher energy needs and therefore consumption. This resulted into 86.4% of expenditure aligned towards it. The strategy adopted was to have a Building Energy Monitoring System (BEMS) that collects the data of usage of energy for illumination, medical gas, air-conditioning, diesel, water expenditure and electrical circuits' maintenance. BEMS detected if there was any deviation from the trends set in system, triggered an alarm to initialize the measures for usage reduction. BEMS Data is analyzed in conjunction with weather conditions at the period, the level of hospital activities at the time and medical equipment operated. Together, such analysis helped to device the best operating energy model suitable for the customized conditions.

Yanzhou People's Hospital (Shandong Province), on the other hand altered its Hospital design into a Green Hospital Design [14]. The design included appropriate positioning of rooms for infectious and aligning the fenestrations according to aspect of building; thereby promoting natural sunlight and ventilation.

Incorporation of energy saving material in the building envelope was performed. Key factors used were, roof garden, permeable pavement, spray cooling for maintaining outdoor thermal environment. China medical university adopted management amelioration by conducting routine energy audits by third party for keeping a track on energy management [15].

For effective energy management, not only do the new hospitals be planned but also the existing needs retrofitting. Considering the number of auditable electrical entities, it becomes primal to list out the components influencing energy consumption. There are 8 retrofitting components identified for Urban India [16]. The water geyser proves to be the most important parameter possessing technical potential in energy saving after tubular fluorescent lamps (TFL), followed by refrigerators, air conditioning, water pumps. The ceiling fan was an entity, altering usage of which contributed for least of the energy saving. Considering facilities located in rural regions, there are 7 components of retrofitting. It is possible to save major chunk of energy by retrofitting refrigerator use followed by TFL, water pumps. Television showed least contribution.

Since, all the hospitals have shown varying adoption in the implementation of any strategy towards the common goal, there is a need of understanding the barriers responsible for all hospitals failing to commonly adopt the systems and implementing them to a 100%. Wang *et.al.* [17], conducted a survey on hindrance to the energy efficient strategies implementation in china. The quantitative survey showcased different concerns depended on the hierarchical levels, namely deputy directors, heads of the departments, and front-line managers and workers. The results showcased that monitory reward would be the most efficient way to encourage the implementation of improved energy efficiency strategies. Political rewards and administrative orders were also deemed to be very important, followed by boosting of the work culture. Such study can be conducted in India to understand the grass root problems in implementing the policies.

García *et.al.* [8], suggested techniques such as domestic water heating, adopting renewable energies, management of the maintenance, thermal insulation improvement, optimal sizing of building (building design), improvement of air conditioning and heating systems, optimizing electric energy installations.

Out of all the possible measures, structural alterations or appropriate material selection of building elements can contribute to better thermal insulating. The surface luminance is the ability to reflect or absorb the light. Higher the surface luminance, higher will be (light power density) LPD for same given source. Thus, for the same LPD, he increase in surface reflectance decreases the light load [18].

Surface reflectance of the interiors plays crucial role in reducing the light load as seen in Figure 2. Ceiling reflect 85% (direct lighting) and at least 90% (indirect and/or daylighting). The walls account for 50% (70% for walls adjacent to daylight apertures). The floors reflect the least, i.e. 20% [4].

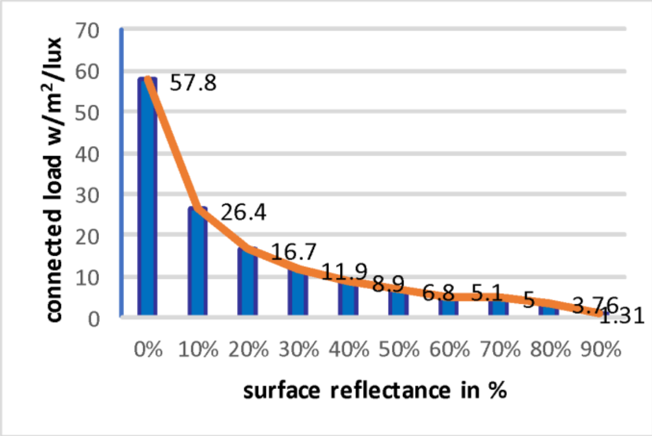

Figure 2: Surface reflectance

For increasing the efficiency of HVAC, various measures are researched and proposed. Installation of occupancy driven wireless thermostats, in which, program driven its operation of systems based on vacancy, can aid in saving 5-10% of the costs incurred [10]. Advanced rooftop unit (RTU) controls have the potential for cutting the HVAC energy use by 20-40%, the set up and selection of components being the prime factors [10]. For retrofitting of the building, the existing windows can be fit with CO2 demand-controlled ventilation (DCV) sensors; this technology coupled with room occupancy sensors can adjust the ventilation accordingly. Solar technology has advanced for higher efficiency in itself. Few measures include altering the arrangement and number of riser tubes, [19]; orientation and tilting angles of collectors – if kept equal to latitude, gives higher efficiency [20].

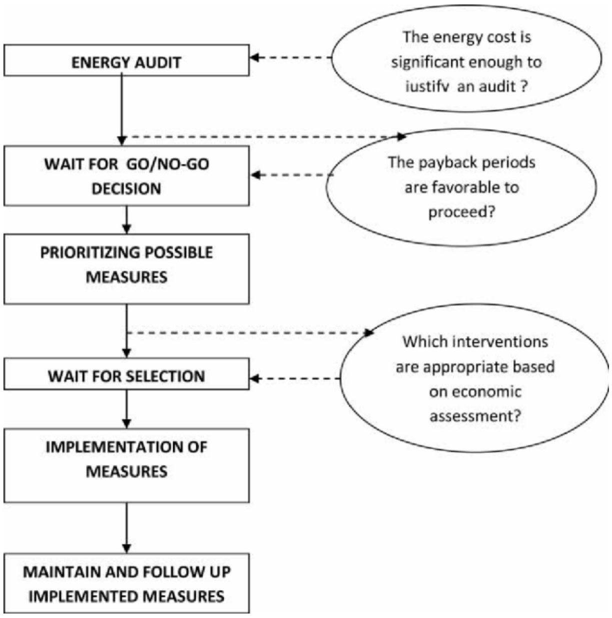

Figure 3: Main phases of an energy management program

Source: [12]

Technical report by National Renewable Energy Laboratory (NERL), [21] has compiled the data of energy management by large hospitals. The focus of the survey is to highlight the adoption of structural array of materials in the design. The aim is to achieve at least 50% energy consumption. The study undertaken in 8 climate zones address the measures undertaken for attaining it namely by use of reduced lighting power density, Daylight sensors, Occupancy detection sensors, enhanced insulation (maximum daylight by opaque exterior and appropriate windows), overhangs over fenestrations towards the south (considering cool breeze), common condenser loop for heat pumps, the temperature of which was maintained using an high efficiency chiller and a boiler. Ventilation controlled on demand, more efficient pumps, reduced infiltration reduction through construction of tighter envelope, subsystems integration for achieving the performance of the entire building performance.

Annual reports of large hospitals mention the devices they incorporated for energy conservation. Table 2 shows a comparative between the adopted choices of leading hospitals of India. Fortis has claimed to have saved 640cr INR amount in 2 years (2015-2017) by adopting energy conservation techniques. “Annual report 2016-2017”, Fortis hospital. The hospitals have adhered to the guidelines put forth by the governing bodies, thus resulting in energy savings as demonstrated in their respective annual reports.

Table 2: Energy conservation technologies adopted by various hospitals

	Apollo	Fortis	Medinova	Naryana diagnostic centre
Led light replacement	yes	yes	yes	yes
Optimizing fuel consumption of boilers	yes	yes		
VFD (Variable frequency drive) installation	yes	yes		yes
Timer based operation for air handling systems	yes	yes		
Using renewable resources	yes	yes		yes
Installing energy efficient equipment	yes	yes	yes	yes
Building management system for HVAC		yes		
Energy optimization in transformers	yes			
Introducing timer control for AHU motors running time	yes			
Optimizing the usage of equipment				
Energy monitoring system				yes

III. DISCUSSION

Using efficient energy saving techniques would reduce global energy consumption intensity and emissions of harmful atmospheric gas. There are many energy conservation technologies with zero investment, like managing the operation time of ventilation units, improving the conditions of contract of electricity. Payback time is crucial for the energy measures requiring finance. For example, LEDs are efficient lighting systems requiring a shorter payback time. Building design, adequate sizing of buildings, efficient thermal insulation, and are the key elements for planned projects. The energy system at a healthcare facility is very crucial and complex and must strictly adhere to the regulations. A regular energy audit is a suitable strategy for optimizing the energy consumption in hospital buildings. In addition, these inspections are useful in prioritizing the necessary measures to reduce the costs of operation and consumption of energy.

For presenting the concepts studied in this paper, some of the models were planned and devised by students of Symbiosis Institute of Technology. The models were prepared using Arduino peripherals and codes available freely online. For the study, the student groups studied the existing facilities of the Institutes, and provided budgetary note for the implementation of the proposed systems. Figure 4 shows a circuit diagram for the proposed assembly to be implemented in lab of which the dimensioning is shown in diagram ab. The activity acquainted the students regarding possible embedment of the systems into commercial infrastructures having intermittent footfall like classrooms, hospital rooms, etc.

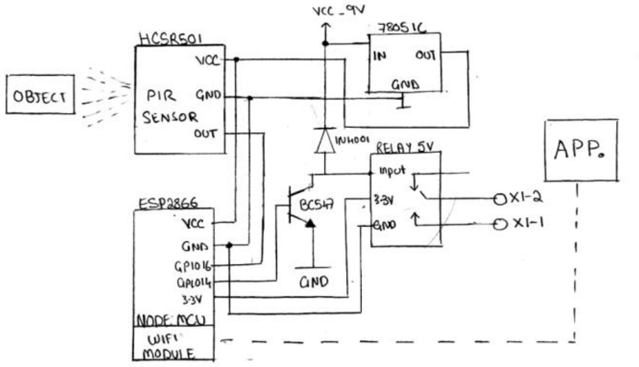

Figure 4: Circuit diagram of the proposed automated lighting system

A mobile application based on IoT was proposed to help observe and analyse the through the app light consumption (IoT), Access to light resource at unauthorized hours, source lab (room) is using light resource.

IV. CONCLUSION

The technology for energy conservation needs to be hand-picked on case-to-case basis according to type of hospitals. Enhancing the thermal insulation is a viable alternative not only during the planning phase, but also for retrofitting. For preventive measures, the prime energy consumption entity being HVAC, there is a need to research on existing HVAC efficiency booster technologies and recommend feasible one by generalizing the application. Replacement of fluorescent and incandescent lamps by LEDs, TEDs, and incorporation of occupancy sensors thereby limiting the intensity of lighting and time control, would be a smarter choice towards the goal. A pool of technology exists, both in research and in the list of ratified technologies. The adoption may depend on multiple factors. Thus, a more comprehensive study is needed in direction of energy saving measures implementation goals and problems associated in hospitals of India. All the lead hospitals follow the regulations laid forward by ECBC, many have actively participated in the Green Building council; however, a focus of study is required on factors affecting motivation of other big players in the Industry to take up the challenge of successful energy conservation implementation. Many solutions exists for planning of hospitals, however, more research needs to be focused on retrofitting existing facilities, thereby aiding conservative measures. IoT seems to be a viable alternative for non-invasive modifications of existing infrastructure. Finally, the successful case-studies can be comprehended quantitatively for forming generalized guidelines for implementation of energy conservation techniques.

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